Field Studies of Subjective Effects on Thermal Comfort in a University Classroom

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Abstract: Two field studies were conducted in a university classroom in the autumn of 2004 in Harbin. The objective of these studies was to assess the thermal conditions and the subjective effects on occupant thermal comfort. A field study was carried out when the undergraduate students were not taught the theory of thermal comfort. A second study was conducted after the undergraduate students knew something about thermal comfort. The thermal comfort variables were measured when the students were filling in the subjective questionnaires on thermal sensation and thermal comfort. A total of 167 sets of questionnaire responses were obtained. The indoor thermal environmental data for the two days are almost the same; however the thermal acceptability is different. The acceptability of the first study is 96.0%, which is higher than the acceptability of 91.5% according to the PPD. In contrast, the acceptability of the second study is 57.4%, which is very low compared with the acceptability of 95.0% according to the PPD. The students' thermal acceptability of the thermal environment before learning the theory of thermal comfort is higher than after learning about thermal comfort. These results confirm the existence of subjective effects on thermal comfort.

Key words: Thermal environment, thermal sensation, thermal comfort, field study, subjective effect

1. INTRODUCTION

Because of the limitation of the climate chamber, many field studies on the thermal comfort have been performed around the world (Webb 1949-1950, Schiller et al. 1988, Leow 1988, Busch 1990, Dedear and Fountain 1994, Donnini et al. 1996, Sharples 1997, Cena and Dedear 1999, Xia et al. 1999, Wang et al. 2003, Wang et al. 2006). This field study was carried out in September 2004 in order to investigate the thermal environment and thermal comfort in a university classroom in Harbin, situated in the northeast of China.

2. OBJECTIVES

The object of this field study is to assess the thermal conditions and the subjective effect on human's thermal comfort.

3. RESEARCH METHODS

The field study was carried out on 16th September 2004 when the undergraduate students were not taught the theory of thermal comfort. The second one was done on 30th September 2004 after the undergraduate students knew something about the thermal comfort. We measured the hourly values of the outdoor dry bulb temperature and relative humidity. And the thermal comfort variables of indoor were measured from 13:30 to 14:30 on these two days when the students were filling in the subjective questionnaires on the thermal sensation and thermal comfort. To avoid the effect of outdoor environment, the study was conducted after the students had been at the classroom for half an hour at least. Objective physical measurements were carried out at five points in each classroom.

The approximate locations of five points are shown in Fig. 1.

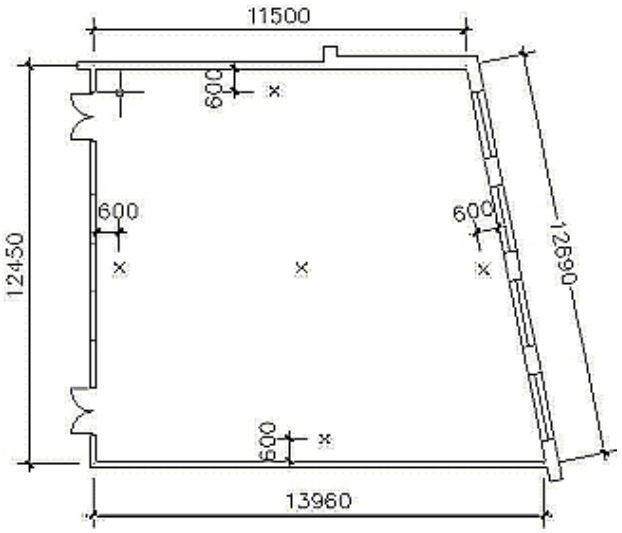

Fig. 1 Plane of measurement points for physical parameters in the classroom

An indoor climate analyzer made in Denmark was used to collect the measured parameters of the indoor environment. The physical data include air temperature, relative humidity, radiant asymmetry, and air velocity. Air temperature and air velocity were measured at the 0.1, 0.6, and 1.1 meter levels, representing the immediate environment of sedentary occupants' ankles, mid-body, and neck, respectively. Relative humidity was measured at the 1.1 meter level. Radiant asymmetry was measured at the 0.6 meter level for seated occupants.

The subjective questionnaires include background survey, clothing and activity checklists, thermal sensation, thermal preference and thermal acceptability survey, thermal comfort and air condition survey and adapted measures survey.

4. RESULTS

4.1 The Outdoor Dry Bulb Temperature and Relative Humidity

The hourly values of the outdoor dry bulb temperature and relative humidity on these two days are presented in Fig. 2 and 3, respectively.

On 16th September, there was a drizzle all day. The mean value of outdoor dry bulb temperature and relative humidity were 20.9 ℃ and 79.2%, respectively. And those were 22.5℃ and 71.3% from 13:00 to 15:00. On 30th September, a shower occurred at 13:00. The mean value of outdoor dry bulb temperature and relative humidity were 6.7℃ and 63.4%, respectively. And those were 6.8℃ and 69.3% from 13:00 to 15:00.

During this field measurement, the windows were open and natural ventilation was used in classrooms. Outdoor environmental parameters may influence indoor physical data as well as subjective evaluation on thermal sensation. When a subject comes into a warm room from outdoor with lower temperature, he feels warmer than before, vice versa.

The outdoor air temperature of 30th September is lower than that of 16th September. On the other hand, indoor air temperature of 30th September is 12~15℃ higher than outdoor temperature. Students should felt warmer when they came into the classroom from outside. However, they felt cold.

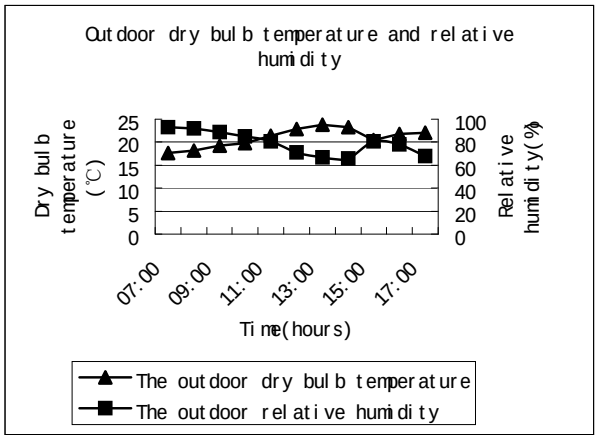

Fig. 2 Outdoor hourly dry bulb temperature and relative humidity on 16th September

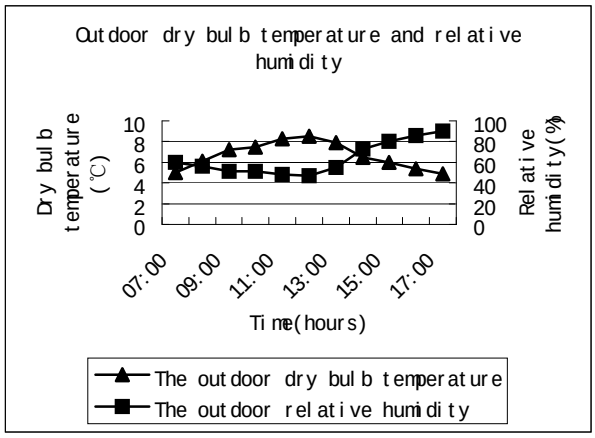

Fig. 3 Outdoor hourly dry bulb temperature and relative humidity on 30th September

4.2 The Indoor Physical Data

The indoor physical data of 16th September and 30th

September are shown in Table 1. The indoor physical data include air temperatures(t_a), relative humidities (φ), air velocities(v), mean radiant temperature(t_r) and operative temperatures(t_o).

Table 1 Indoor physical data

	16th September	30th September
t_a /℃	26.0	21.6
φ	55%	34%
v/m•s^{-1}	0.15	0.12
t_r/℃	25.9	22.8
t_o/℃	25.9	22.2

4.3 The Background of the Occupants

167 sets of questionnaire responses were obtained. The results about the background of the subjects are given in Table 1 and 2. And the subjects participating on 16th were composed of 69 females (69.7%) and 30 males (30.3%) and that on 30th were composed of 49 females (72.1%) and 19 males (27.9%). Table 2 and 3 show that most students adapted the climate of Harbin when they have been in Harbin for more than 4 years averagely.

Table 2 Statistics on the subjects on 16th September

	Age / years	Length of time Living in Harbin/years
Mean	23.2	4.0
Standard deviation	0.99	5.31
Maximum	26	23
Minimum	20	2

Table 3 Statistics on the subjects on 30th September

	Age / years	Length of time Living in Harbin/years
Mean	23.1	4.8
Standard deviation	1.02	6.72
Maximum	26	24
Minimum	20	2

4.4 The Insulation of Clothes

The insulation of clothes (clo) is obtained from tables (ISO 7730) based on clothes checklists. The insulation of clothes of 16th is 0.57clo (0.088 m^2 K / W) and that of 30th is 1.0clo (0.155 m^2 K / W). On average, the chair insulation increment amounts to 0 clo (McCullough et al. 1994).

4.5 Metabolic Rates

During the measuring, the students were sitting and filling in the questionnaires, the metabolic rates (met) of the subjects are estimated to be, on average, 1.2 met (70 W/m^2).

4.6 PMV-PPD

The values of calculation of *PMV*(Predicted Mean Vote) and *PPD*(Predicted Percentage of Dissatisfied) indices are given in Table 4.

The thermal comfort condition regulated by ASHRAE 55-2002 comfort standard is *PPD*<20% (the natural ventilation). The indoor environment of 16th September is slightly warmer than neutral, and *PPD* is 8.5%, which is less than 20%. And that of 30th September is slightly cooler than neutral, and *PPD* is 5.0%, which is less than 20%. The indoor environment of 30th September is more comfortable than that of 16th September.

Table 4 Results of PMV-PPD indices

	16th September	30th September
PMV	0.4096	-0.0197
PPD	8.4971	5.008

4.7 Thermal Sensation

The distribution of *TSV* (Thermal Sensation Vote) on 16th and 30th September is shown in Fig. 4 and 5.

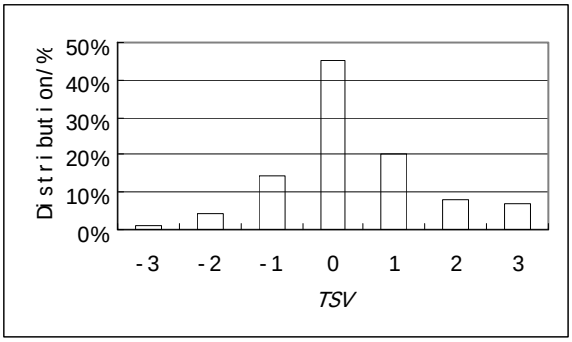

Fig. 4 Distribution of thermal sensation votes on 16th September

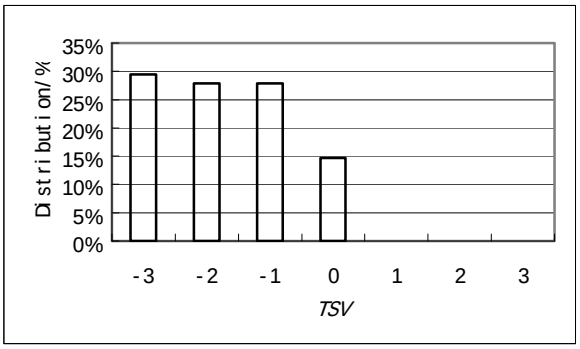

Fig. 5 Distribution of thermal sensation votes on 30th September

The statistics of thermal sensation votes is given in Table 5.

Table 5 Statistics of thermal sensation votes

	16th September	30th September
Mean	0.32	-1.72
Standard deviation	1.21	1.05
Maximum	3	0
Minimum	-3	-3

From the table we can see that there are deflections between *MTS* (Mean Thermal Sensation) and *PMV*. *MTS* (0.32) of 16th September is lower than *PMV* (0.4096), which shows that the students' thermal sensations of 16th September are closer to the thermal neutrality than the prediction. *MTS* (−1.72) of 30th September is lower than *PMV* (−0.0197), which shows that the students' thermal sensations of 30th September are more uncomfortable than the prediction.

4.8 Thermal Acceptability

The indoor thermal environmental data for the two days are almost the same, however the acceptability is different. The acceptability of the first study is 96.0%, which is higher than the acceptability (91.5%) according to the *PPD*. On the opposite, the acceptability of the second study is 57.4%, and it is very low compared with the acceptability (95.0%) according to the *PPD*.

5. CONCLUSIONS

The indoor thermal environment is comfortable according to the *PMV-PPD* indices.

MTS of 16th September is close to *PMV*, but *MTS* of 30th September is much lower than *PMV*. The deflection between *MTS* and *PMV* of 30th September is more evident than that of 16th September.

The acceptability of the first study is closer to the acceptability according to the *PPD* than that of the second study.

PPD of 16th September is higher than that of 30th September. However, the acceptability of that day is higher than the latter. Because the students had not learned some knowledge about thermal comfort until 28th September. This shows that students are sensitive to the environment after they have some knowledge about thermal comfort. And they are more expected to the environment than before.

The students' thermal acceptability for thermal environment before learning the theory of thermal comfort is higher than that after they have learned the knowledge about thermal comfort. This indicates that the subjective effect on the thermal comfort exists.

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